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(54) CIRCUIT INTERRUPTER HAVING DUAL-BORE ARC EXTINGUISHING MEANS

(71) We, WESTINGHOUSE ELECTRIC CORPORATION, of Three Gateway Center, Pittsburgh 30, Pennsylvania, United States of America, a corporation organized and existing under the laws of the Commonwealth of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to high voltage circuit interrupters and more particularly to high voltage fuse structures. The invention disclosed in the present application involves the use of the inventions disclosed and claimed in the following co-pending applications: 32835/68 (Serial No. 1,200,703), 32836/68 (Serial No. 1,200,704), 33636/68 (Serial No. 1,200,705), 34071/68 (Serial No. 1,200,706), and 34072/68 (Serial No. 1,200,707).

In power fuses of the dual-bore type which have a relatively large main bore and a relatively small auxiliary bore extending through a body of arc-extinguishing or gas evolving material, a problem arises in insuring that the arcing which results during an interrupting operation is always initiated in the smaller auxiliary bore of the interrupter and that such arcing remains in the smaller auxiliary bore to be finally interrupted when relatively smaller fault currents are being interrupted which the interrupter is incapable of interrupting in the larger main bore. If the body of arc-extinguishing material in such an interrupter includes a plurality of generally annular blocks each of which includes a relatively large opening and a relatively small opening with the openings in the respective blocks being substantially aligned when the blocks are assembled or stacked in end-to-end relation to form the respective bores of the interrupter, ionized gases may escape from the small bore to the main bore during an interrupting operation of the interrupter when the interrupter is attempting to interrupt relatively low fault currents, such as 1000 amperes or less, to cause a restrike of the arc in the main bore in which the interrupter is incapable of interrupting such relatively low fault currents.

The principal object of this invention is to provide a power fuse construction of the dual-bore type including means for joining a plurality of blocks of arc-extinguishing material around the relatively smaller bore of the power fuse such that the escape of ionized gases from the relatively small bore to the relatively large bore is prevented.

With this object in view, the present invention resides in a circuit interrupter comprising a tubular insulating casing, a body of gas evolving, arc-extinguishing material disposed inside of and spaced from the ends of the casing and comprising a plurality of generally cylindrical blocks stacked axially in end-to-end relation, each of said blocks having a relatively large opening and a relatively small opening extending therethrough parallel to the axis with the large openings and the small openings, respectively, being substantially aligned, a conducting member disposed in the small openings for interruption of small current arcs, and a conducting member disposed in the large opening for interruption of large current arcs, said conducting members being connected to separate fusible members, each block having formed in its meeting face with another block a recess extending around the small opening in spaced relationship therefrom, each recess extending to the outer perphery of the respective block, and an electrically insulating, bonding material disposed within and substantially filling the space formed by each pair of recesses at the meeting ends of adjacent blocks thereby to prevent gases from travelling between the small and the large openings.

The invention will become more readily apparent from the following description of a preferred embodiment thereof shown, by way of example only, in the accompanying drawings, in which:

Figure 1 is a side elevational view of a high voltage power fuse structure which embodies the principles of the present invention and which is shown vertically mounted in the normally closed operating condition.

Fig. 2 is an enlarged longitudinal, sectional view of a fuse unit which forms part of the fuse structure shown in Fig. 1 with portions of the end fittings of the fuse unit omitted.

Fig. 3 is a bottom view of a generally annular block of gas evolving material which forms part of a body of arc-extinguishing material which is incorporated in the fuse unit of Fig. 2; and

Fig. 4 is an enlarged partial side elevational view of parts of the adjacent blocks of gas evolving material which form part of the fuse unit shown in Fig. 2 illustrating the manner in which the adjarent blocks of gas evolving material may be joined together in accordance with the invention.

As illustrated in Fig. 1, the fuse structure 10 is supported by a base (not shown) formed of sheet metal and a pair of outwardly extending insulator supports 272 and 282. The upper insulator support 272 fixedly supports in position a latching assembly 250 which includes a break contact 252. A lower insulator support 282 supports a hinge assembly 260 which pivotally supports a fuse unit 100 and which includes a hinge contact 262. As illustrated in Fig. 1, the fuse unit 100 serves to electrically bridge the break contact 252 and the hinge contact 262 so that electric current will normally pass therebetween by way of terminal pads (not shown) to which an external, electrical circuit may be connected.

As illustrated in Fig. 2 the fuse unit 100 includes a generally tubular fuse holder 32 which is formed from a suitable weatherproof, electrically insulating material, such as a glass fiber reinforced epoxy resin, and a pair of upper and lower end fittings or terminals 34 and 36, respectively, which are disposed at the opposite ends of the holder 32 and which are formed from an electrically conducting material. The upper and lower end fittings or terminals 34 and 36, respectively, are securely fastened to the opposite ends of the associated holder or tube 32 by suitable means, such as cement, and a plurality of pins which pass transversely through both the end fittings and the associated holder 32. As illustrated, the fuse unit 100 also includes a hook eye 274 which is pivotally mounted on a laterally projecting portion 34A of the upper end fitting 34 and which may be utilized for effecting opening and closing movements of the fuse unit 100 by means of a conventional hook-stick. The lower end fitting 36 incudes a hinge lifting eye 284 which may be formed integrally with the lower end fitting 36 and which may be employed in conjunction with a conventional hook-stick to effect physical removal of the fuse unit 100 from the hinge assembly 260 for replacement of the fuse unit 100. The lower end fitting or terminal 36 also includes an inwardly projecting flange portion 36B against which the lower end of the holder 32 bears, as shown in Fig. 2.

The fuse unit 100 further includes a renewable or refillable unit 20 mounted within the holder structure and includes also the outer tube 32 and the upper and lower end fittings or terminals 34 and 36, respectively. The renewable unit 20 includes its own supporting tube or insulating casing 108 which is formed from a suitable electrically insulating material having sufficient strength to withstand the internal gas pressures and intense heat which result during an interrupting operation of the fuse unit 100, such as glass fiber reinforced epoxy resin. A body of gas evolving material, such as boric acid, which may include a plurality of generally annular blocks 122, 124 and 126 and 128 is disposed inside the tube 108 and spaced from the ends thereof. Each of the blocks 122, 124, 126 and 128 includes a relatively larger central opening, as indicated at 125 for the block 126 in Fig. 3 and a relatively smaller opening at one side thereof, as indicated at 127 for the block 126 in Fig. 3, both of which extend axially through the individual blocks. When the blocks 122, 124 126 and 128 are axially stacked in end-to-end relation as shown in Fig. 2, with the respective larger and smaller openings thereof substantially aligned, a main bore 130 is formed through the body of gas evolving or arc-extinguishing material which includes said blocks and a relatively smaller auxiliary bore 192 is formed through the body of gas evolving material.

In order to prevent the travel of ionized gases between the main bore 130 and the auxiliary bore 192 during an interrupting operation of the fuse unit 100 and, more specifically, to prevent the escape of ionized gases from the auxiliary bore 192 into the main bore 130 during an interrupting operation of the fuse unit 100, the meeting surfaces of the blocks 122, 124, 126 and 128 are structurally joined to one another around the relatively smaller openings of said blocks which form the auxiliary bore 192 by an electrically insulating, thermosetting, sealing and bonding material having a relatively high dielectric strength, such as an epoxy resin. More specifically, the meeting surfaces of the blocks 122, 124, 126 and 128 at each end thereof include a groove or recess, as indicated at 126B for the block 126 in Fig. 3, which extends substantially around and is spaced from the relatively smaller opening in each of said blocks as indicated at 127 for the block 126 in Fig. 3. As shown in Fig. 3, the recess or groove 126B is spaced from the relatively smaller opening 127 and the block 126 by a generally tubular portion of the block 126, as indicated at 126C. When the blocks 122, 124, 126 and 128 are assembled in end-to-end relation as shown in Fig. 2, the recesses or grooves in the meeting surfaces of the adjacent blocks are disposed in substantially congruent relation so that each groove or recess, as indicated at 126B, for the block 126 in Fig. 3 forms with the recess in

the adjacent block a larger passageway which extends substantially around the auxiliary bore 192 and the smaller openings of the successive blocks which make up the auxiliary bore 192 with the ends of the recesses being open at the outer periphery of the respective blocks, as shown in Fig. 4, for the blocks 126 and 128. The passageway which is formed by each pair of adjacent grooves or recesses in the meeting surfaces of each pair of blocks is substantially filled with a thermosetting, electrically insulating sealing and bonding material, as indicated at 132, in Fig. 2. It is to be noted that in Fig. 3 the tubular portion 126C which is disposed inside the recess 126B is also spaced from the outer periphery of the block 126 to permit the application of the sealing and bonding material 132 completely around the entire periphery of the joint between the successive blocks to prevent the escape of ionized gases from the auxiliary bore 192 into the main bore 130 of the fuse unit 100.

After the blocks 122, 124, 126 and 128 are stacked in end-to-end relation, but before the blocks are assembled inside the tube 108, the sealing and bonding material or cement 132 can be forced or inserted into the passageways formed around the auxiliary bore 192 between each pair of meeting surfaces of said blocks by the use of a pressure gun to thereby seal and join the successive blocks to one another around the auxiliary bore 192. It should be noted that because of the spacing of the recess 126B from the relatively smaller opening 127 in the block 126, the sealing and bonding material is prevented from entering either the small bore 192 or the main bore 130 which might adversely affect the arc-extinguishing characteristics of the blocks 122, 124, 126 and 128 while still permitting a visual inspection of the ends of the joint to insure that a seal and joint is formed around the entire periphery of the blocks adjacent to the auxiliary bore 192. A relatively high dielectric ring seal is thus provided around the joint between each pair of successive blocks with a dielectric strength equal to or greater than the dielectric strength of the material from which the blocks are formed. It will be noted that the disclosed construction also provides mechanical reinforcement of the blocks at the joints between the successive blocks around the auxiliary bore 192. It is important to note that since the passageways or recesses provided in the meeting surfaces of the blocks 122, 124, 126 and 128 extend around the smaller openings provided in the respective blocks which form part of the auxiliary bore 192 with the ends of each passageway or recess exposed at the outer periphery of the respective blocks, the complete filling of each recess or passageway may be observed when the sealing and bonding material is flowed into the recess or passageway at one side of the smaller opening of each block when the material flows out the other end of the passageway at the other side of the smaller opening in each block.

In order to limit the gas pressures which result during an interrupting operation of the fuse unit 100, each of the blocks 126 and 128 includes a generally C-shaped recess as indicated at 129 in Figs. 2 and 3 which extends axially from one end of each of said blocks to a point which is adjacent to and axially spaced from the other end of the respective blocks with each of the recesses terminating peripherally short of the portion of said blocks which includes the relatively smaller opening which forms part of the auxiliary bore 192. Each of the blocks 126 and 128 therefore includes around the major portion of its inner periphery an integral frangible inner wall, as indicated at 126A for the block 126 in Fig. 3. The inner walls 126A and 128A are arranged to disintegrate when the fuse unit 100 is called upon to interrupt relatively large current and when intense heat results within the main bore 130 and the gas pressure within the main bore 130 exceeds a predetermined value. During such an interrupting operation, the size of the main bore 130 through the blocks 126 and 128 is effectively increased by the disintegration of the inner walls 126A and 128A of the blocks 126 and 128 respectively to thereby increase the size of the gas passageway in the main bore 130 and decrease or limit the gas pressure that would otherwise result.

In order to retain the blocks 122, 124, 126 and 128 in assembled relationship with the associated tube 108, as shown in Fig. 2, the outer surfaces of said blocks may be coated with suitable cement or bonding material, such as an epoxy bonding material, prior to assembly of the blocks inside the tube 108. In addition, a generally tubular or annular retaining member or plug 189 may be disposed at the upper end of the blocks 122, 124, 126 and 128 with the major portion of the retaining member 189 extending axially inside the tube 108. The retaining member 189 may be formed or molded from a suitable electrically insulating material having sufficient strength to assist in retaining the blocks 122, 124, 126 and 128 in assembled relationship with the tube 108 during an interrupting operation of the fuse unit 100, such as a glass polyester material. A washer 183 formed from similar material may be disposed between the retaining member 189 and the block 122 and may be employed during the preassembly and bonding of the blocks 122, 124, 126 and 128 together prior to the assembly of said blocks inside the tube 108. It is to be noted that the retaining member 189 as well as the washer 183 includes a relatively larger central opening which forms an extension of the main bore 130 and a relatively smaller opening which forms an extension of the auxiliary bore 192.

In order to assist in retaining the member 189 in assembled relation with the associated tube 108 during an interrupting operation of the fuse tube 100, the outer surface of the retaining member 189 and the inner surface of the tube 108 at the upper end of the tube 108 include adjacent helical grooves which together form a passageway in which a helical wire 191 is disposed to firmly secure the retaining member in assembled relation with the tube 108. The retaining member 189 may be assembled with the upper end of the tube 108 by first assembling the helical wire 181 in the helical groove around the outer surface of the retaining member 189 and then screwing the retaining member 189 into the upper end of the tube 108 to the final position shown in Fig. 2. It is to be noted that the outer surface of the retaining member 189 may also be coated with a suitable cement or bonding material, such as an epoxy bonding material, to additionally secure the retaining member 189 to the tube 108.

In order to substantially prevent the escape of ionized gases from the upper end of the refillable or renewable unit 20 around the elongated conducting member 83 which extends through the main bore 130, a generally tubular member 185 is disposed in concentric or nested relation with the retaining member 189, as shown in Fig. 2, and is preferably formed from an electrically insulating material having a relatively low coefficient of friction, such as polytetrafluoroethylene which is sold under the Trade Mark "Teflon". A shoulder portion 185A is provided at the upper end of the tubular member 185 and includes an opening of reduced cross-section or size through which the conducting member 83 passes and which forms a substantially gas-tight seal with the conducting member 83 during an interrupting operation of the fuse unit 100 when the conducting member is actuated to move axially upwardly, as viewed in Fig. 2. The tubular member 185 also acts as a bearing to guide the axial movement of the conducting member 83. In order to prevent the tubular member 185 from being blown out of the upper end of the tube 108 during an interrupting operation of the fuse unit 100, the retaining member 189 includes an inner shoulder portion against which the upper end of the tubular member 185 bears, as shown in Fig. 2. The escape of ionized gases from the upper end of the renewable unit 20 from the auxiliary bore 192 may be adequately prevented by reducing the size of the relatively smaller opening through the retaining member 189 through which the auxiliary conductor 182 passes so that the cross-section of the auxiliary conductor 182 substantially fills the relatively smaller opening through the retaining member 189.

In order to further assist in retaining the blocks 122, 124, 126 and 128 in assembled relationship with the tube 108 during an interrupting operation of the fuse unit 100, a generally tubular or annular retaining member 142 is disposed inside the tube 108 at the lower end of the blocks 122, 124, 126 and 128, as shown in Fig. 2, and is formed or molded from an electrically insulating material having sufficient strength to assist in retaining the blocks 122 through 128 inside the tube 108 during such an interrupting operation, such as a glass polyester material. The outer surface of the retaining member 142 is preferably coated with a suitable cement or bonding material, such as an epoxy bonding material, prior to the assembly of the retaining member 142 inside the tube 108. This bonding material serves to bond the retaining member 142 to the inside of the tube 108. The retaining member 142 includes a relatively larger opening which extends axially therethrough, as indicated at 142A, into which the lower end of the main bore 130 opens and which may serve as an exhaust passageway for high pressure gases which result during the operation of the fuse unit 100. The opening 142A also serves as a chamber in which the fusible means 160 is disposed. The retaining member 142 also includes a relatively smaller opening 142B which extends axially therethrough. The lower end of the auxiliary bore 192 opens into the opening 142B and the lower end of the auxiliary conductor 182 projects in the same opening. The insulating wall or partition 142C which is formed integrally with the retaining member 142 around the relatively smaller opening 142B through the retaining member 142 assists in preventing certain arc products which may result during the operation of the fuse unit 100 in a relatively smaller opening 142B of the retaining member 142 from being deflected into the relatively larger opening 142A of the retaining member 142 and impinging on parts of the fusible means 160. The retaining member 142 also includes an upwardly projecting tubular portion 142D adjacent to the relatively smaller opening 142B through the retaining member 142 with the projecting portion 142D being joined to the adjacent block 128 around a recess in the block 128 which is adapted to receive the projecting portion 142D by a flexible bonding material, such as silicone rubber. This joint between the retaining member 142 and the block 128 around the auxiliary bore 192 assists in preventing the travel or escape of ionized gases between the auxiliary bore 192 and the main bore 130 and between the auxiliary bore 192 and the relatively larger opening 142A through the retaining member 142 during an interrupting operation of the fuse unit 100.

The elongated conducting member or rod 83 of the refillable unit 20 is normally disposed, as shown in Fig. 2, to extend through the main bore 130 with the upper end of the conducting rod 83 projecting axially beyond

the upper end of the tube 108 and with the upper portion of the conducting rod being externally threaded, as indicated at 83A. The conducting rod 83 is normally held in the position shown in Fig. 2 by a connection through the fusible means 160 to the generally annular or tubular lower conducting member or contact 150.

More specifically, the fusible means 160 comprises a strain element 162 and a fusible element or link 164. The upper end of the strain element 162 is secured by suitable means, such as brazing, to the lower end of the conducting rod 83, while the other end of the strain element 162 is secured by suitable means, such as brazing to the connecting conductor or terminal 156 which is of the flat strip type. The connecting conductor 156 is secured in turn to the lower contact 150 adjacent to the upper end of the lower contact 150 by suitable means, such as brazing. Similarly, the upper end of the fusible element or link 164 is secured to the lower end of the conducting rod 83 by suitable means, such as brazing, while the lower end of the fusible element or link is secured to the lower contact 150 adjacent to the upper end of the lower contact 150 by suitable means, such as brazing. It is to be noted that the strain element 162 and the fusible element 164 are electrically connected in parallel between the lower end of the conducting rod 83 and the lower contact 150 of the renewable unit 20.

Similarly, the auxiliary conductor 182 which is of a relatively smaller cross-section or size than the conducting rod 83 normally extends through the auxiliary bore 192 with the upper end of the auxiliary conductor extending axially beyond the upper end of the auxiliary bore 192 and being both mechanically and electrically connected to the upper portion of the conducting rod 83 by a transversely extending spring pin 184. The pin 184 is disposed in a transversely extending recess or opening provided in the upper end of the retaining member 189 to prevent rotation of the conducting rod 83 after assembly of the rod 83 in the renewable unit 20. The upper end of the auxiliary conductor 182 may be formed as a loop which is assembled over the conducting spring pin 184 and retained thereon by the head 186 of the spring pin 184. The lower end of the auxiliary conductor 182 extends or projects into the relatively smaller opening 142B of the retaining member 142, as shown in Fig. 2, and is electrically connected through a helical conducting wire of reduced cross-section, as indicated at 194, to an angle-shaped auxiliary stationary terminal 157 which is secured to the tubular conducting member 150 adjacent to the upper end of the member 150 by suitable means, such as brazing. The upper end of the helical wire 194 which is disposed inside the relatively smaller opening 142B of the retaining member 142 is secured to the lower end of the auxiliary conductor 182 by suitable means, such as brazing, and the lower end of the helical wire 194 is secured to the auxiliary terminal 157 by suitable means, such as crimping or brazing.

The lower contact or conducting member 150 also includes an elongated arcing terminal 158, which projects upwardly from the upper end of the contact 150 into the relatively smaller opening 142B of the retaining member 142 to axially overlap the lower end of the auxiliary conducting member 182 with the lower portion of the arcing terminal 158 being disposed adjacent to and generally parallel to the axis of the helical wire 194. The arcing terminal 158 is electrically insulated along its length by a coating or film of electrical insulating material, such as an insulating enamel, which is provided on the arcing terminal 158 to prevent the electrical shorting out of the helical wire 194. The arcing terminal 158 which is formed from an electrically conducting material may be structurally secured to the upper end of the lower contact 150 at the inner periphery thereof by suitable means, such as brazing, or may be formed integrally therewith in a particular application. It is to be noted that the auxiliary current path which extends from the upper portion of the conducting rod 83, through the cross pin 184, the auxiliary conductor 182 and the helical wire 194 to the auxiliary terminal 157 on the lower contact 150 is also electrically connected in parallel with the conducting paths which include, respectively, the strain element 162 and the fusible element 164.

In order to assist in retaining the blocks 122 and 128 and the retaining member 142 in assembled relationship inside the tube 108, as well as for another important purpose during the interrupting operation of the fuse unit 100, the lower tubular conducting member or contact 150 includes a main portion 152 which extends axially inwardly from the lower end of the tube 108 to bear against the lower end of the retaining member 142. The lower contact 150 also includes a flange portion 154 at the lower end thereof against which the lower end of the tube 108 bears when the conducting member 150 is assembled with the fuse tube 108.

In order to retain the lower contact 150, as well as other parts of the renewable unit 20, in assembled relationship with the tube 108 during an interrupting operation of the fuse unit 100, a generally tubular external terminal member or ferrule 172 is disposed to telescope over the lower end of the tube 108. In order to firmly secure the external terminal member 172 to the lower end of the tube 108, the internal surface of the external terminal member 172 and the external surface of the portion of the tube 108 adjacent to the member 172 include adjacent helical grooves which, when

the parts are assembled, form a helical passageway in which a helical wire 173 is disposed. In the assembly of the external terminal member 172 on the lower end of the tube 108, the helical wire 173 may be first assembled in the helical groove on the lower end of the tube 108 and the external terminal member 172 may then be screwed onto the lower end of the tube 108 until the parts reach their final positions, as shown in Fig. 2. In order to additionally assist in retaining the external terminal member 172 on the lower end of the tube 108, the outer surface of the tube 108 and the inner surface of the external terminal member 172 may be coated with a cement or bonding material, such as an epoxy bonding material, prior to the assembly of the external terminal member 172 on the lower end of the tube 108. It is to be noted that the external terminal member 172 also includes an inwardly projecting flange portion 172A around a central opening 172B which bears against the adjacent flange portion 154 of the tubular conducting member 150 to assist in retaining the tubular conducting member 150 in assembled relation with the other parts of the renewable unit 20.

In order to form a current conducting path which extends between the lower end fitting 36 and the lower contact 150 of the renewable unit 20, the external terminal member 172 also includes an external flange portion 172C which bears against the inwardly projecting flange portion 36B of the lower end fitting 36. The electrically conducting path thus formed extends from the lower contact 150 through the inwardly projecting flange portion 172A of the external terminal 172 and through the externally projecting flange portion 172C to the inwardly projecting flange portion 36C of the lower end fitting 36. The area of the current transfer path between the external terminal member 172 of the renewable unit 20 and the lower end fitting 36 may also be augmented by the contact ring 195 which may be formed of electrically conducting material and which is disposed to threadedly engage the internally threaded opening at the lower end of the end fitting 36 and bear against the external terminal member 172 of the renewable unit 20, as shown in Fig. 2.

It is important to note that in order to prevent the concentration of relatively high potential stresses adjacent to the external terminal member 172 during an interrupting operation of the fuse unit 100 at relatively high voltages, the upper end of the lower contact 150 extends axially beyond the upper end of the external terminal member 172 toward the other end of the tube 108 a minimum distance to prevent such a concentration of relatively high potential stresses externally of the tube 108 adjacent to the external terminal member 172.

In order to actuate the axial movement of the conducting rod 83 as well as that of the auxiliary conductor 182 during an interrupting operation of the fuse unit 100 and to electrically connect the renewable or refillable unit 20 just described to the upper end fitting or terminal 34, a spring and cable assembly 30 is disposed inside the outer tube 32 between the renewable unit 20 and the upper end fitting 34. The spring and cable assembly 30 includes at its lower end a generally tubular conducting member or socket 84 having an internally threaded central opening, as indicated at 84A, to receive the upper threaded end 83A of the conducting rod 83. A lower spring seat member 86 is fixedly mounted on the socket 84 for movement therewith by assembling the spring seat 86 over the outer periphery of the socket 84 with the lower end of the spring seat 86 bearing against a shoulder provided on the outer periphery of the socket 84 and with the upper end of the spring seat 86 being engaged by a plurality of portions of the socket 84 at the upper end of the socket 84 which serves to stake or secure the spring seat 86 on the socket 84. The spring and cable assembly 30 also includes an upper spring seat 74 which is slidably disposed over the lower portion 60A of a generally cylindrical conducting member 60 whose integral upper portion 60B extends axially through an opening 34B in the upper end fitting 34 and is externally threaded at the upper end thereof, as indicated at 60C. As illustrated, the generally cylindrical conducting member 60 may be secured to the upper end fitting 34 by an internally threaded end cap 44 which may be screwed down on the upper threaded portion 60C of the conducting member 60 until the flange portion 44A of the end cap 44 bears against the upper end fitting 34 around a flange or shoulder portion, as indicated at 34C in Fig. 2. A helical tension spring 76 is secured at its upper end to the external, helically threaded portion of the upper spring seat 74, while the lower end of the spring 76 is secured to the external, helically threaded portion of the lower spring seat 86 to bias the conducting rod 83, as well as the auxiliary conductor 182, in a generally upward direction, as viewed in Fig. 2, away from the lower contact 150. It is important to note that the turns of the spring 76 are generally rectangular or square in cross-section to substantially prevent any overlapping of the turns 76 and the consequent damage to the spring 76 that might otherwise result during an interrupting operation of the fuse unit 100.

In order to electrically connect the renewable unit 20 and more specifically the conducting rod 83 to the upper end fitting 34 both prior to and during an interrupting operation of the fuse unit 100, a plurality of helically coiled flexible cables or conductors 82 and electrically and structurally connected at the bottom ends thereof to the conducting socket 84 into separate openings (not shown) provided in the socket 84 by suitable means, such as

brazing or by staking, and at the upper ends thereof are secured to the conducting member 60 in separate openings provided in the conducting member 60 by suitable means, such as brazing or staking. In order to increase the effective current transfer area between the conducting member 60 and the upper end fitting 34, a washer 54 formed of electrically conducting material may be disposed between the shoulder which is formed at the intersection of the upper and lower portions 60A and 60B, respectively, of the conducting member 60 and the shoulder which is formed inside the upper end fitting 34, as indicated at 34D around the central opening 34B.

In order to facilitate the assembly of the renewable unit 20 and the associated spring and cable assembly 30 inside the outer holder 32 as will be explained hereinafter, a pair of cross pins 58 may be disposed in associated openings provided at the opposite sides of the upper portion 60B of the conducting member 60 to be positioned finally within an enlarged central opening or recess 34E in the upper end fitting 34, as shown in Fig. 2.

In order to actuate the release of the latching assembly 250 shown in Fig. 1 following an interrupting operation by the fuse unit 100, a tripping rod or member 52 is slidably disposed inside a central opening or passageway 72 which is provided in the conducting member 60 with the upper end of the tripping rod 52 being normally positioned below the top of the end cap 44, as shown in Fig. 2. The lower end of the tripping rod 52 is fixedly coupled to the upper spring seat 74 for axial movement therewith by the cross pin 56 which passes laterally through aligned transverse openings in the tripping rod 52 and the upper spring seat 74 and through a pair of elongated slots 62 provided at the opposite sides of the conducting member 60 with the cross pin 56 being normally positioned at the lower end of the slots 62, as shown in Fig. 2. In order to permit the axial movement of the tripping rod 52 upwardly through the end cap 44 following an interrupting operation of the fuse unit 100, the top of the end cap 44 includes a central opening 46 through which the tripping rod 52 may pass to actuate the release of the latching assembly 250 shown in Fig. 1. When the latching assembly 250 is released by the movement of the tripping rod 52, the upper end of the fuse unit 100 will be actuated to rotate in a clockwise direction, as viewed in Fig. 1, about the lower hinge assembly 260 to thereby provide an electrically insulating gap between the upper break contact 252 and the lower stationary hinge contact 262 by such drop-out action.

In order to assemble the renewable unit 20 and the associated spring and cable assembly 30 into the outer holder 32, the threaded end of the conducting rod 83 is first screwed into the socket 84 at the lower end of the spring and cable assembly 30. A refill fusing tool (not shown) is then screwed into the internally threaded central opening or passageway 72 at the other end of the spring and cable assembly 30. The spring and cable assembly 30 is then inserted into the outer holder 32 with the upper end of the spring and cable assembly 30 being inserted first into the lower end of the outer holder 32, as viewed in Fig. 2, until the refill tool (not shown) passes through the central opening 34B or the upper end fitting 34. By use of the refill tool, the spring 76 is stretched and placed in tension until the cross pins 58 mounted at the sides of the conducting member 60 are drawn upwardly through a pair of radial slots (not shown) provided in the upper end fitting 34 around the central opening 34B. The upper conducting member 60 and the spring and cable assembly 30 are then rotated until the pins 58 rest on the shoulder provided at the bottom of the enlarged opening 34E in the upper end fitting 34. The end cap 44 may then be screwed down on the upper threaded portion 60C of the conducting member 60 to further stretch the spring 76 to the final condition or position shown in Fig. 2 in which the cross pins 58 are drawn upwardly away from the shoulder in the upper end fitting 34 at the bottom of the enlarged opening 34E. It is to be noted that when the spring and cable assembly 30 and the renewable unit 20 are assembled inside the outer holder 32, as just described, the cross pin 56 which couples the upper spring seat 74 to the tripping rod 52 is disposed at the bottom of the slot 62 at the opposite sides of the conducting member 60 to permit limited upward travel of the upper spring seat 74 along with the cross pin 56 and the tripping rod 52 to a final position of the tripping rod 52 in which the tripping rod 52 projects beyond the end cap 44 axially to release the latching assembly 250 as previously mentioned. The washer 54 also acts as a stop surface against which the upper end of the spring seat 74 bears to limit the upward travel of the tripping rod 52, the cross pin 56 and the spring seat 74.

In considering the operation of the fuse unit 100, it is to be noted first that the current paths which include, respectively, the strain element 162, the fusible element 164 and the helical wire 194, which is connected in series with the auxiliary conductor 182, are all electrically connected in parallel between the upper end of the conducting rod 83 and the lower contact 150 at the lower end of the renewable unit 20. The resistance of the current path which includes the fusible element 164 and which is calibrated to have predetermined time-current characteristics is arranged to be relatively much less than the resistance of either the path which includes the strain element 162 or the path which includes the helical wire 194 so that normally most of the current which flows through the fuse unit 100

is carried by the fusible element 164. Although the resistance of the current path which includes the strain element 162 is relatively greater than the resistance of the path which includes the fusible member 164, the resistance of the path which includes the strain element 162 is relatively less than that of the path which includes the helical wire 194 so that when the fusible element 164 melts or blows, most of the current which was formerly carried by the fusible element 164 is then transferred to the strain element 162. In other words, when the current which is flowing through the unit 100 increases to a value which is of sufficient magnitude and duration to melt or blow the fuse element 164, most of the current which is flowing through the fuse unit 100 then transfers to the strain element 162. When the current which is transferred to the strain element 162 after the melting of the fusible element 164 is sufficient to melt or blow the strain element 162, the current which was previously carried by the strain element 162 is finally transferred to the current path through the auxiliary bore 192 which includes the auxiliary conductor 182 and the helical wire 194. No arcing occurs as these elements melt because of the parallel electrical path through the helical wire. When the strain element 162 melts or blows, the conducting rod 83 is no longer restrained from upward movement under the influence of the biasing spring 76 and the conducting rod 83 and the auxiliary conductor 182 will start to move upwardly under the influence of the spring 76 to thereby stretch the helical wire 194 which is electrically connected to the bottom of the auxiliary conductor 182. It is to be noted that the stretching of the helical wire 194 permits limited travel of both the conducting rod 83 and the auxiliary conductor 182 while maintaining a continuous electrical circuit through the auxiliary bore 192 and that as long as the current path which includes the auxiliary conductor 182 and the helical wire 194 is intact, no arcing will take place in either the main bore 130 or in the auxiliary bore 192. In other words, the stretching of the helical wire 194 during the initial movement of the conducting rod 83 and the auxiliary conductor 182 following the melting or blowing of the fusible element 164 and the strain element 162 will permit the formation of an electrically insulating gap in the main bore 130, while initially maintaining a conducting path and delaying the formation of an insulating gap in the auxiliary bore 192.

After the strain element 162 melts or blows as just described, and the conducting rod 83 and the auxiliary conductor 182 begin to move upwardly to thereby stretch the helical wire 194, the helical wire 194 will either fracture mechanically when stretched to its limit or the current transferred to the current path which includes the auxiliary conductor 182 and the helical wire 194 will be sufficient to melt or blow the helical wire 194 which is of reduced cross-section compared with that of the auxiliary conductor or rod 182. After the helical wire 194 is melted or otherwise broken, an arc will be initiated between the retreating end of either the broken helical wire 194 or the auxiliary conductor 182 and the arcing terminal 158 which axially overlaps the lower end of the auxiliary conductor 182 to thereby burn through the electrical insulation on the arcing terminal 158. Even after the wire 194 melts or is broken, the formation of the significant electrically insulating gap in the auxiliary bore 192 is further delayed by the overlapping of the auxiliary conductor 182 by the arcing terminal 158 until the retreating free end of either the wire 194 or the conductor 182 passes the upper end of the arcing terminal 158 whose insulation will have burned through by this time. It is important to note that the insulating gap in the main bore 130 between the separated ends of the conducting parts will increase at a faster rate than the formation of an insulating gap in the auxiliary bore 192 due to both the delay in the formation of an arc in the auxiliary bore 192 because of the presence of the helical wire 194 and due to the overlapping of the auxiliary conductor 182 by the arcing terminal 158. It is also important to note that the arcing which takes place in the fuse unit 100 during an interrupting operation will always take place initially in the auxiliary bore 192, as just explained. When the retreating end of either the helical wire 194 or the auxiliary conductor 182 passes the upper end of the arcing terminal 158, the arcing which takes place initially in the auxiliary bore 192 will cause gases to be evolved from the gas evolving material around the auxiliary bore 192 which will be un-ionized.

When the current to be interrupted by the fuse unit 100 is relatively low, such as 1000 amperes or less, and when the gas pressure of the evolved gases in the auxiliary bore 192 increases to thereby increase the dielectric strength in the auxiliary bore 192, the insulating gap which is formed in the auxiliary bore 192, along with the corresponding increased dielectric strength, will be sufficient to interrupt the alternating current following a particular current zero in the auxiliary bore 192. The insulating gap which is formed simultaneously in the main bore 130 of the fuse unit 100 at a relatively faster rate will have sufficient dielectric strength considering the instantaneous potential difference between the separating conducting parts in the main bore 130 of the fuse unit 100 to prevent a restrike of the arc in the main bore 130 for such relatively low fault currents. In other words, when any fault current is interrupted by the fuse unit 100, as just described, arcing will always be initiated in the auxiliary bore 192 and for

relatively small fault currents, the arcing which results will be finally interrupted in the auxiliary bore 192. One important reason for this is that the relative dielectric strength of the gap in the main bore 130 at the time that the arc is finally interrupted in the auxiliary bore 192 will be relatively higher than that in the auxiliary bore 192 to prevent a restrike or breakdown of the main bore 130 due to the potential difference which results between the separated conducting parts in the main bore 130.

For relatively higher fault currents, the arcing which is initiated in the fuse unit 100 will still be initiated in the auxiliary bore 192 in the manner just described. For such relatively higher current faults however, the gas pressure which builds up in the auxiliary bore 192 during an interrupting operation and the burning back of the separated conducting parts in the auxiliary bore 192 will result in a relatively higher deielectric strength in the auxiliary bore 192 compared with that in the main bore 130 between the separated conducting parts in the main bore 130. If the instantaneous potential difference between the separated ends of the conducting parts in the main bore 130 is sufficient when the dielectric strength of the main bore 130 becomes relatively less than that of the auxiliary bore 192, the arc will restrike in the main bore 130 to thereby cause the evolution of un-ionized gases in the main bore 130 to thereby increase the gas pressure in the main bore 130, as well as the corresponding dielectric strength in the main bore 130. The arc which restrikes in the main bore 130 will be elongated both by the upward movement of the conducting rod 83 and by the burning back of the separated conducting parts in the main bore to thereby increase the quantity of un-ionized gases evolved from the gas evolving material around the main bore 130. The arc in the main bore 130 will be finally interrupted following a particular current zero in the alternating current which is being interrupted when the insulating gap and the corresponding dielectric strength in the main bore 130 is sufficient to withstand the instantaneous potential difference between the separated conducting parts in the main bore 130. If the fault current which is being interrupted is of a relatively still higher magnitude, the gas pressure in the main bore 130 along with the intense heat which results may be sufficient to disintegrate the inner walls of the blocks 126 and 128 to thereby limit the gas pressure of the evolved gases to a value within the rupture strength of the tube 108, as previously explained. It is to be noted that when the arc is interrupted in the main bore 130, as just described, to thereby cause the evolution of gas from the gas evolving material in the blocks 122, 124, 126 and 128 which surround the main bore 130, the upward movement of the conducting rod 83 along with the upward movement of the auxiliary conductor 182 will be additionally accelerated by the force of the gas pressure of such evolved gases in the main bore 130 along with the force exerted on the conducting rod 83 by the biasing force of the spring 76.

During an interrupting operation of the fuse unit 100 as just described, when the conducting rod 83 is released and moved upwardly under the influence of the spring 76 or under the influence of both the spring 76 and the gas pressure of the evolved gases inside the renewable unit 20, the turns of the spring 76 which are normally held in tension will partially collapse toward a compressed condition but after the turns of the spring 76 collapse to a certain extent, the upper spring seat 74 will slide axially on the lower portion of the conducting members 60 until the upper end of the spring seat 74 impacts or bears against the washer 54 to thereby drive or actuate the tripping rod 52 in an upward direction, as viewed in Fig. 2. The tripping rod 52 will be actuated from the position shown in Fig. 2 until the upper end of the tripping rod actuates the release of the latching means 250. It is to be noted that the upward movement of the conducting rod 83 and the auxiliary conductor 182 will establish the insulating gaps previously described between the separated ends of the conducting parts inside the renewable unit 20 following an interrupting operation. In addition, the fuse unit 100 will be actuated by the release of the latching means 250 by the tripping rod 52 to rotate in a clockwise direction about the lower hinge assembly 260 in a drop-out movement to establish a larger insulating gap between the break contact 252 and the lower stationary hinge contact 262 of the fuse structure 10.

It is important to note that during an interrupting operation of the fuse unit, as previously described, for either relatively low fault currents or for relatively high currents, the gas seal and joint structure between the successive blocks 122, 124, 126 and 128 as previously disclosed substantially prevents the escape of ionized gas from the auxiliary bore 192 in which all arcing initially takes place to the main bore 130 along the meeting surfaces of the successive blocks in the renewable unit 20. As previously mentioned, if such ionized gases were permitted to escape into the main bore 130, a restrike might result when the fuse unit 100 is called upon to interrupt relatively low fault currents and the restrike of an arc in the main bore would result in an arcing condition which the fuse unit 100 is incapable of interrupting for relatively low fault currents. This is because for relatively low fault currents, the quantity of gas evolved in the main bore 130 is not sufficient to establish a dielectric strength in the main bore 130 which will

be great enough to interrupt the arc which results in the main bore 130.

It is to be understood that the teachings of the applicants' invention may be applied to power fuses for high voltage applications which are not of the drop-out type. It is also to be understood that the teachings of the applicants' invention may be applied to power fuses for high voltage applications which do not include a tubular conducting member or shield, such as the lower contact 150 shown in Fig. 2, but which instead employ for example a lower contact ring.

The apparatus embodying the teachings of this invention have several advantages. For example, the joints between the plurality of blocks which make up the body of arc-extinguishing or gas-evolving material in a circuit interrupter as disclosed are sealed to prevent the escape or travel of ionized gases from the auxiliary bore to the main bore which might cause a restrike of the arc in the main bore which the circuit interrupter is incapable of interrupting. In addition, the disclosed construction provides mechanical reinforcement of the gas evolving blocks at the joints around the auxiliary bore which extends through said blocks. A further advantage of the disclosed joint construction is that the joint provides improved dielectric strength between the adjacent blocks of gas evolving material around the auxiliary bore even though the edges of the blocks may be chipped or damaged during the assembly of the blocks in the manufacture of the overall circuit interrupter. A final advantage of the disclosed construction is that a positive seal is provided in the joints between the adjacent blocks.

WHAT WE CLAIM IS:—

1. A circuit interrupter comprising a tubular insulating casing, a body of gas evolving, arc-extinguishing material disposed inside of and spaced from the ends of the casing and comprising a plurality of generally cylindrical blocks stacked axially in end-to-end relation, each of said blocks having a relatively large opening and a relatively small opening extending therethrough parallel to the axis with the large openings and the small openings, respectively, being substantially aligned, a conducting member disposed in the small openings for interruption of small current arcs and a conducting member disposed in the large openings for interruption of said large current arcs, said conducting members being connected to separate fusible members, each block having formed in its meeting face with another block a recess extending around the small opening in spaced relationship therefrom, each recess extending to the outer periphery of the respective block, and an electrically insulating, bonding material disposed within and substantially filling the space formed by each pair of recesses at the meeting ends of adjacent blocks thereby to prevent gases from travelling between the small and the large openings.

2. A circuit interrupter as claimed in claim 1, wherein said electrically insulating, bonding material is an epoxy resin.

3. A circuit interrupter as claimed in claim 1 or 2, wherein at least one of the blocks includes a generally C-shaped recess which partially surrounds the large opening and extends parallel to the axis from one end of the block to a point which is spaced axially from the other end of the block with the smaller opening of the block being disposed between the peripheral ends of the C-shaped recess.

4. A circuit interrupter as claimed in claim 1, 2 or 3, wherein the conducting means between which an arc is drawn includes a fusible conducting member and means for actuating the conducting means to separate upon the fusing of the fusible conducting member.

5. A circuit interrupter as claimed in any one of claims 1 to 4 and substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

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1200702 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

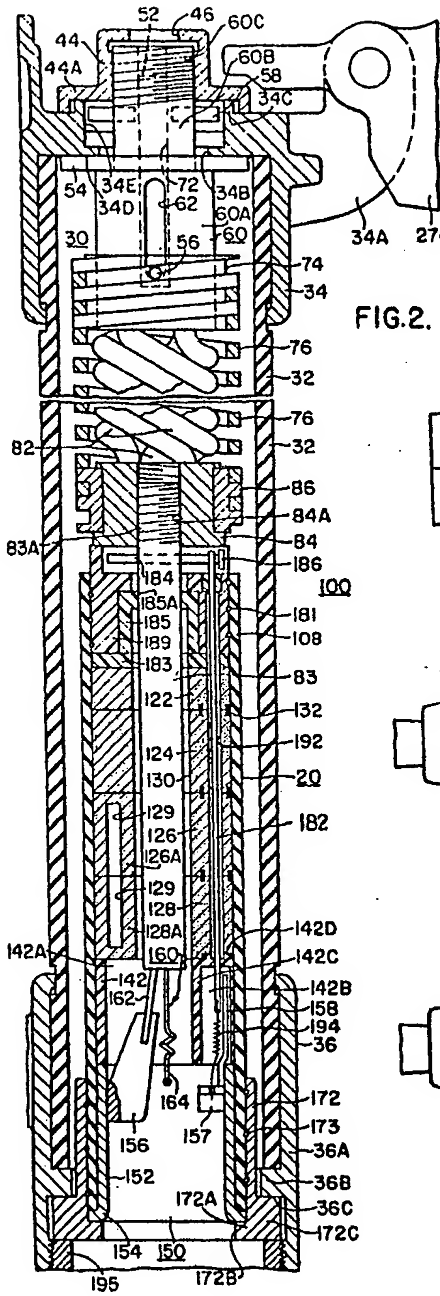
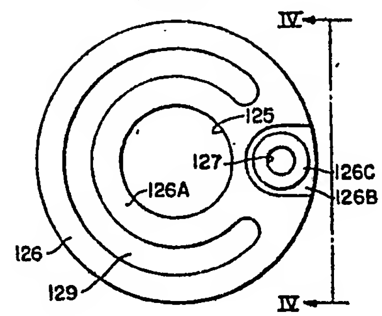


FIG.2.

FIG.3.



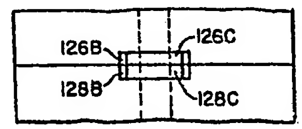


FIG.4.

FIG.1.